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Genesis Radiation Environment

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Overview

- Survey and Examination of Eroded Returned Surfaces (SEERS) Project
- Genesis spacecraft
- Genesis reference radiation environment
- Summary

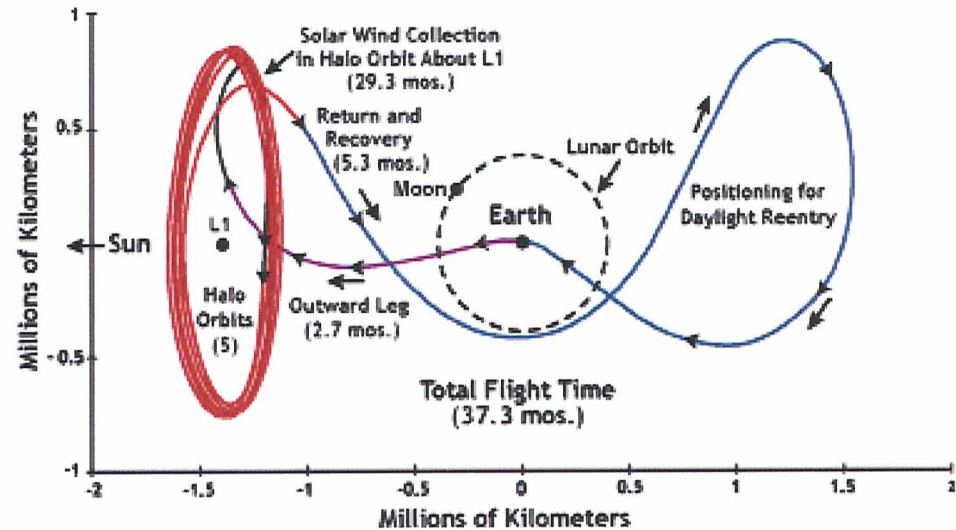
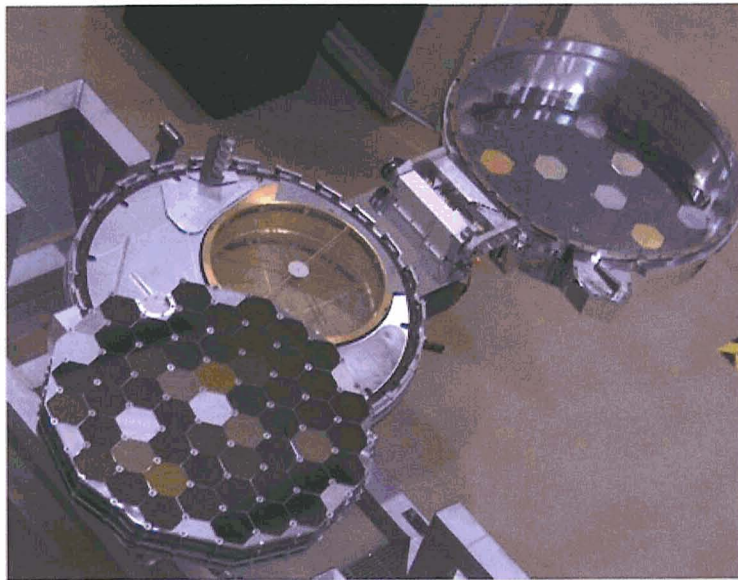
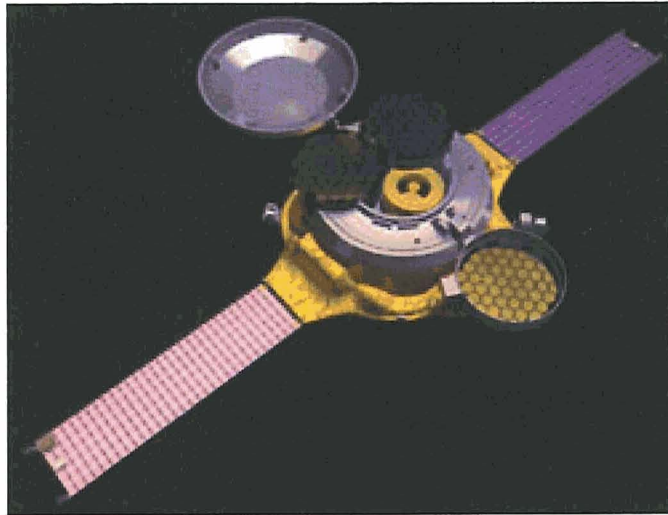


Overview

- Unique opportunity learn about L1 charged particle environment interactions with spacecraft from studying Genesis returned hardware:
 - L1 charged particle environments
 - Degradation of surface materials (compaction, erosion, pitting)
 - Radiation damage of materials
 - Validation of solar wind/radiation effects models
 - Spacecraft charging
 - Analysis of arc damage sites
 - Validation of charging models (surface, internal)
- Outline:
 - Genesis spacecraft
 - Solar wind/energetic particle environments
 - Charging/electrical discharge
 - Summary



Genesis/L1 Radiation Environment



Science Capsule open 1 Dec 2000 to 1 April 2004

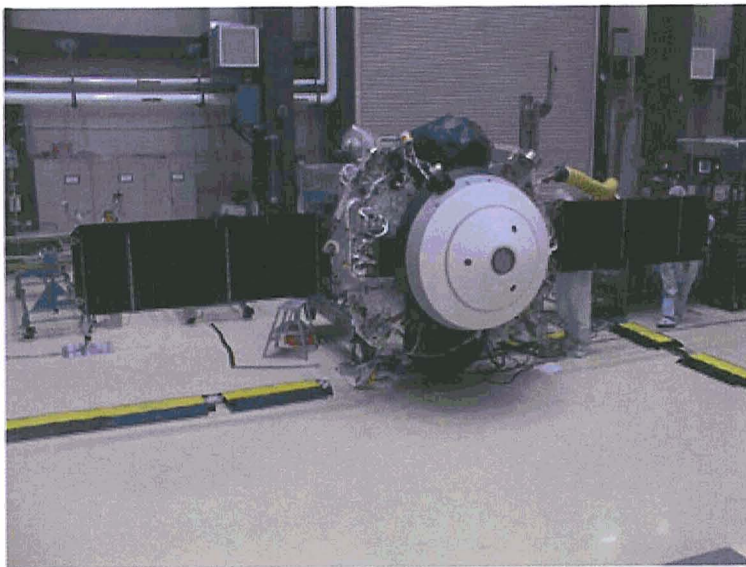
--GIM ion moments available on LANL website

--No electron data

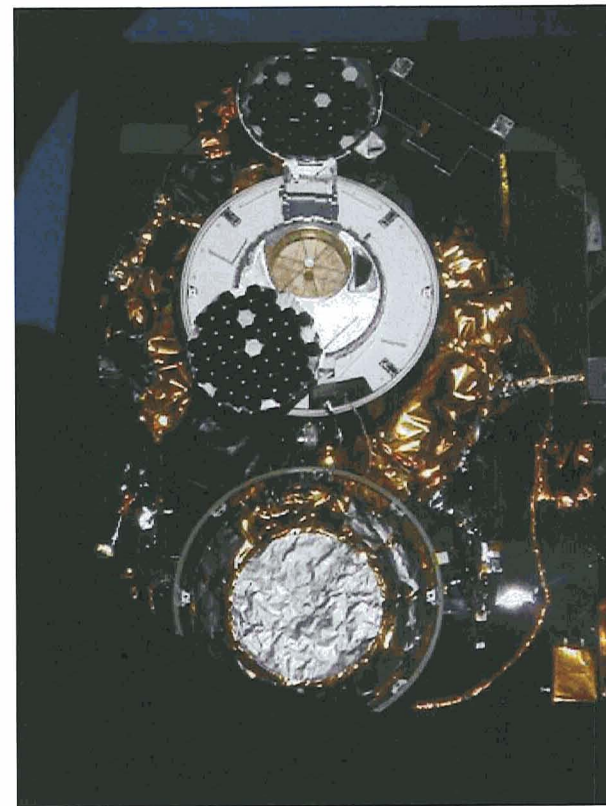


Genesis Radiation Model

- Differential flux radiation environment for space exposed materials on Genesis spacecraft
- Support materials evaluation of returned hardware for Survey and Examination of Eroded Returned Surfaces (SEERS) program



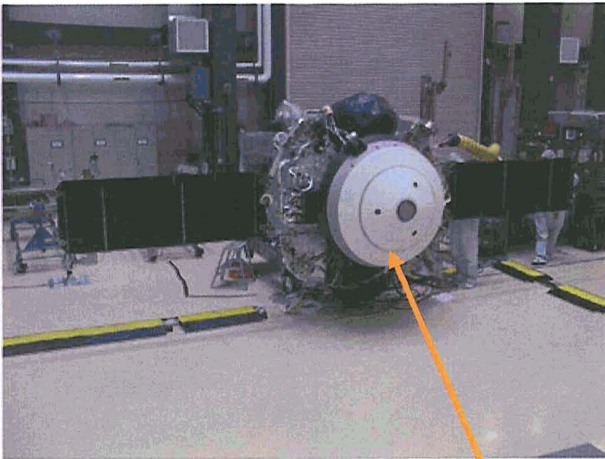
- Model will be completed even though future of SEERS is uncertain



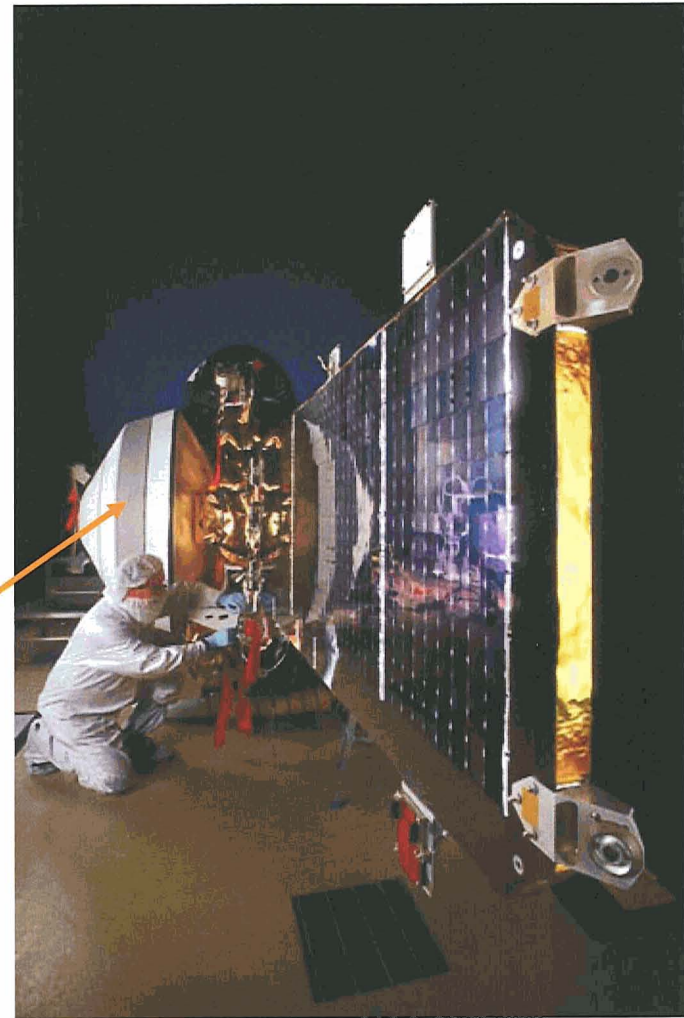


Genesis Spacecraft

Only the Sample Return Capsule
(SRC) will be returned to Earth!



SRC



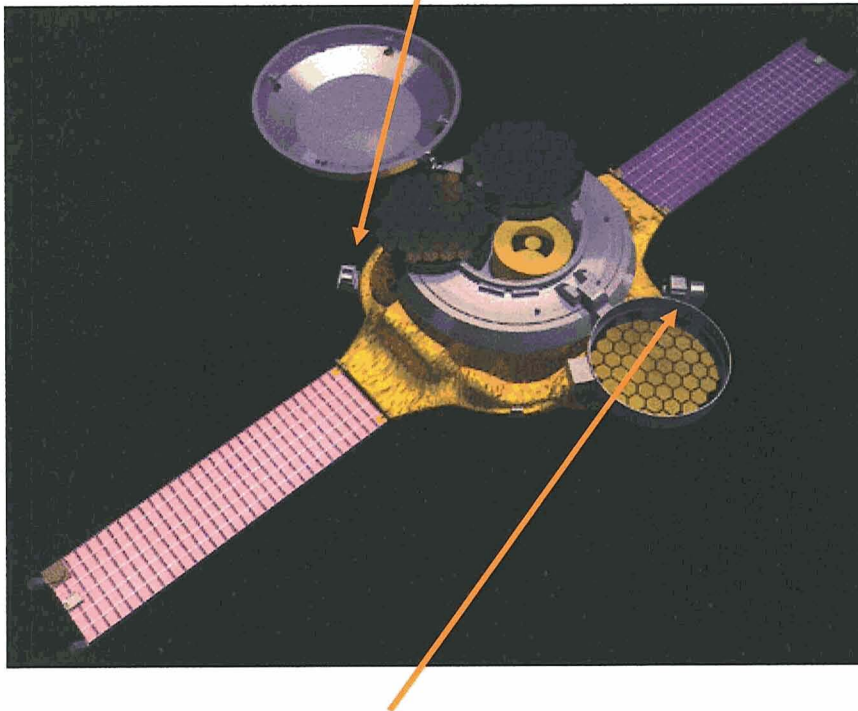
AIAA ASM 2006
Reno, NV January 2007



Genesis Spacecraft

Genesis Ion Monitor (GIM)

- 40 energy steps, 200 eV – 25 keV
- Complete 3-D ion (H^+ , He^{++}) spectra every 4 spins (at 1.6 rpm)

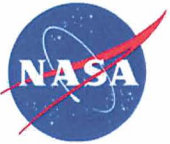


Genesis Electron Monitor (GEM)

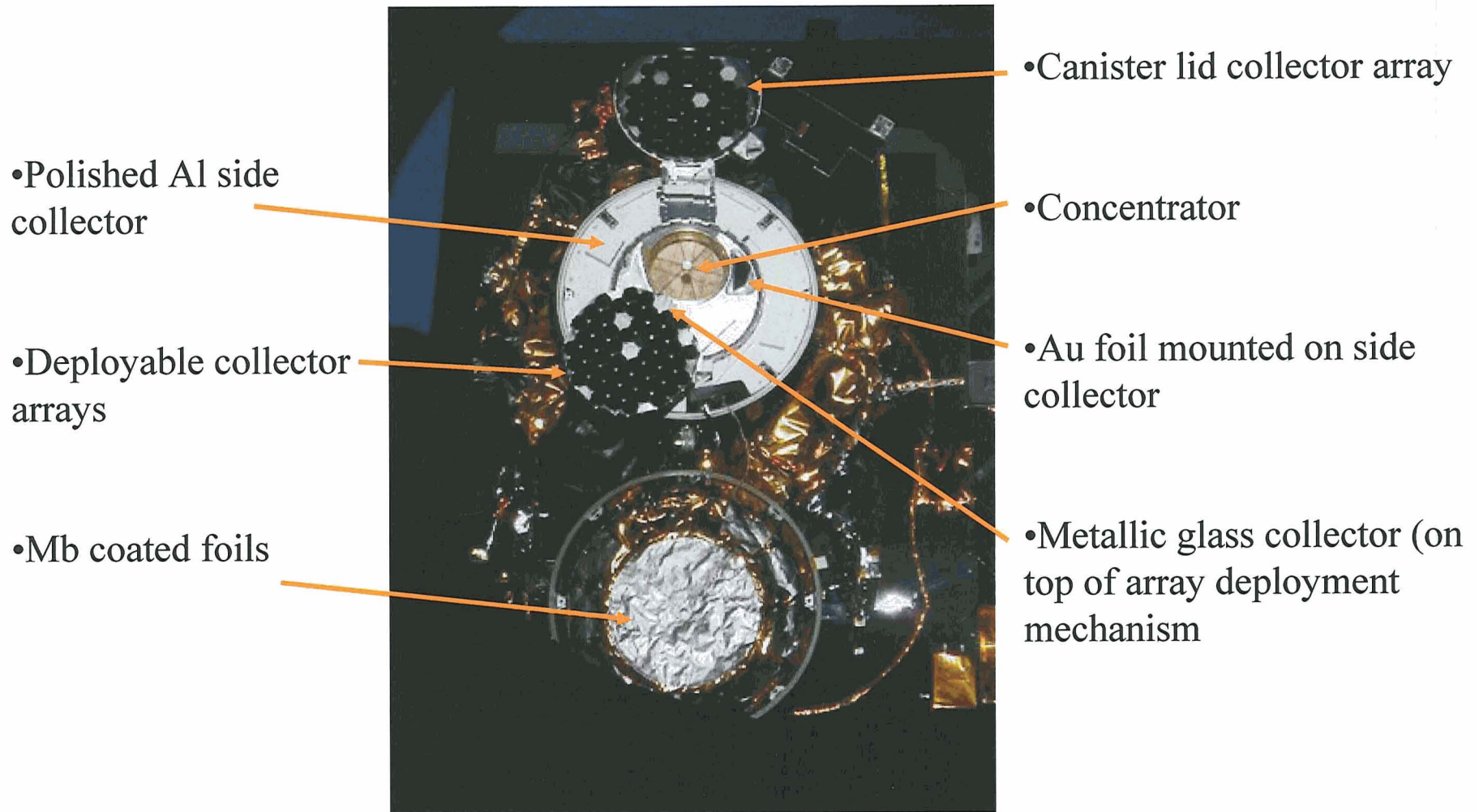
- 24 energy steps, 1.5 eV – 1 keV, 3-D spectra

GEM/GIM role:

- Provide data to spacecraft control and data handling system to select the appropriate solar wind collector array
 - Algorithm uses data to determine solar wind regime
- Provide solar wind electron/ion data to science community

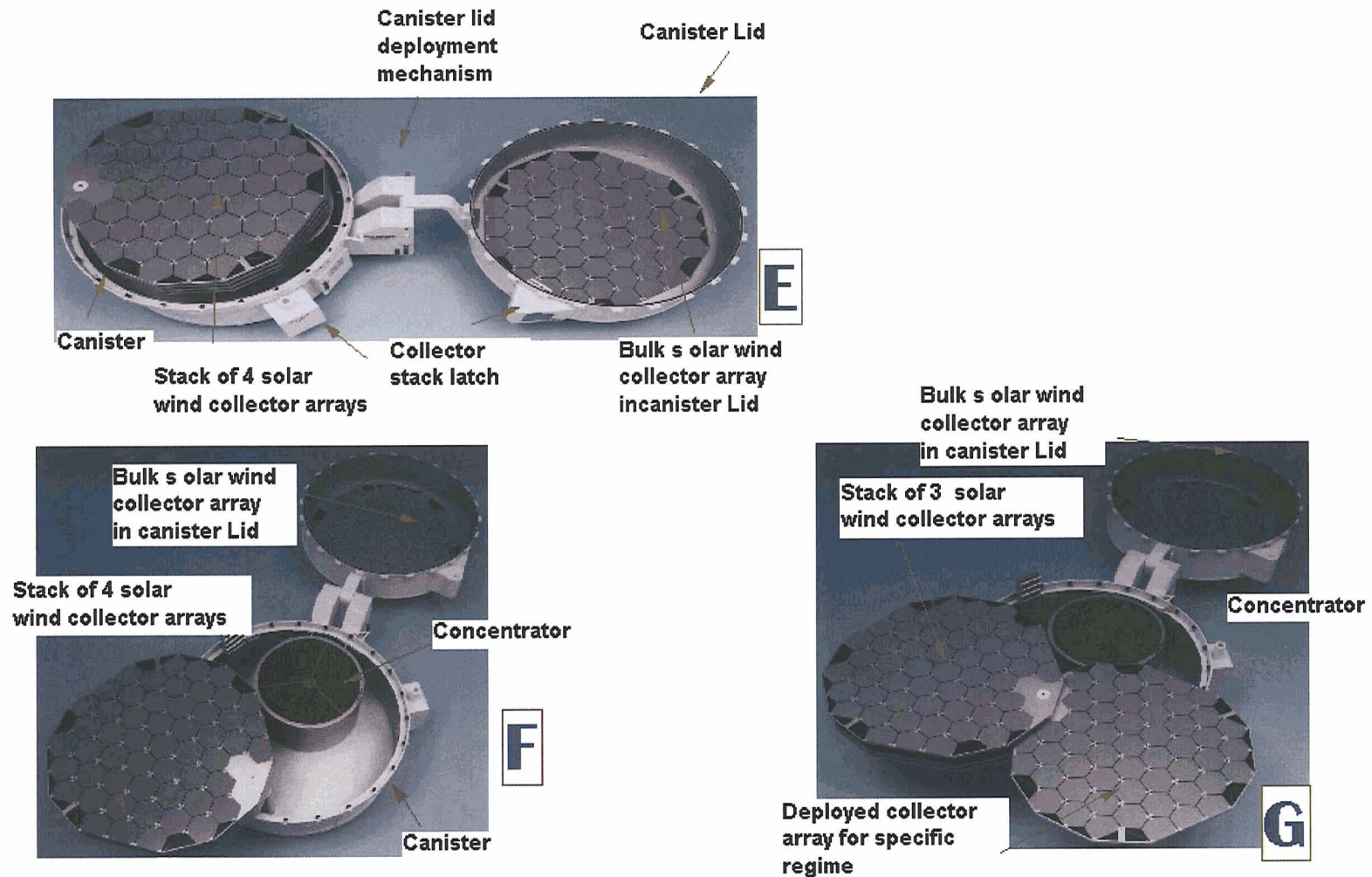


SRC Interior





Collector Array Deployment

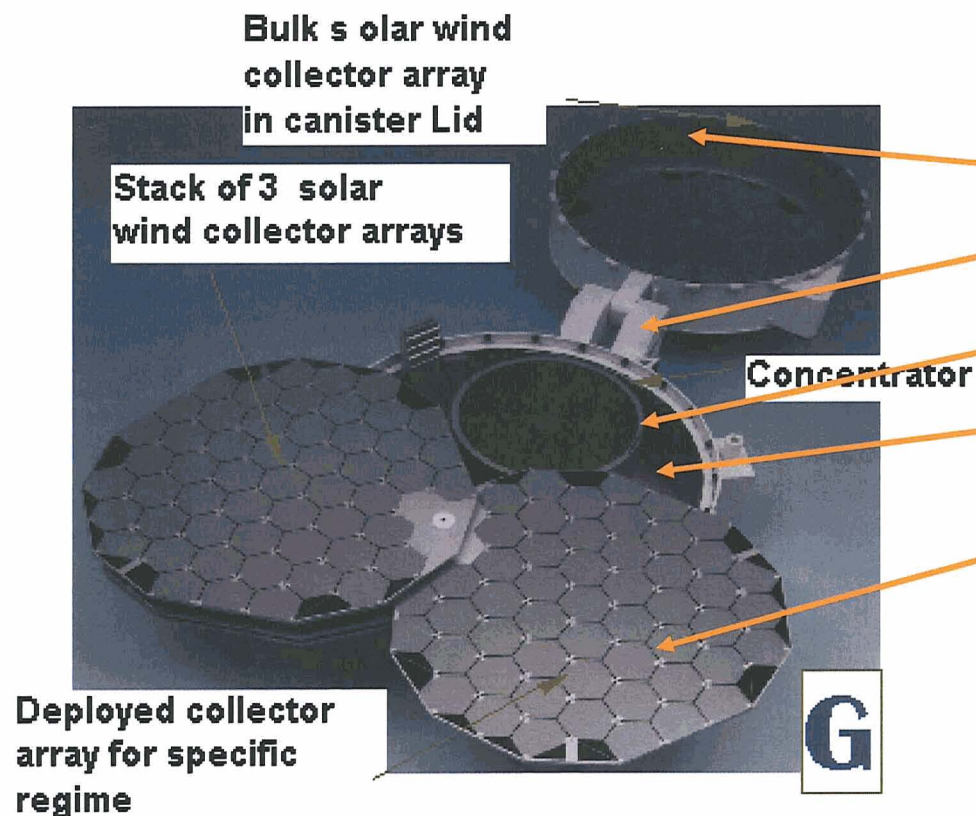


(from <http://www.gps.caltech.edu/genesis/fig2-2.html>)

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Arrays During Science Operations

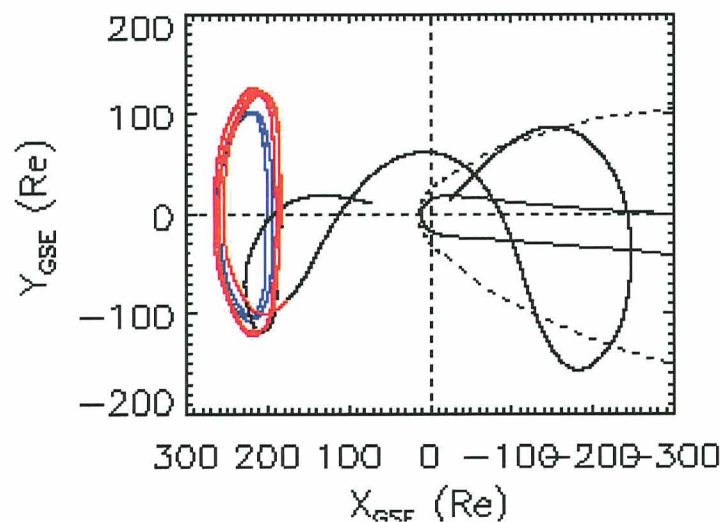
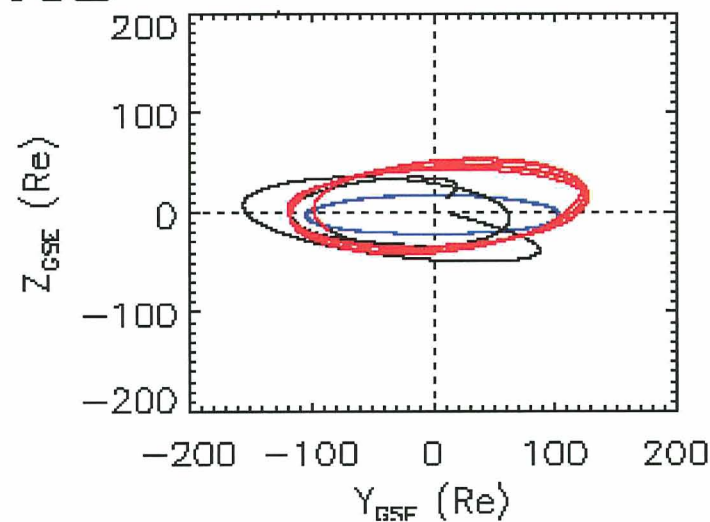
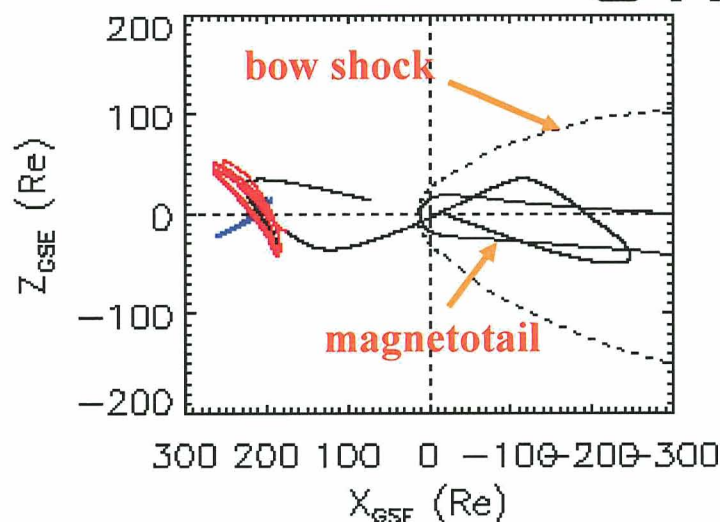


Sites for solar wind impingement studies:

- Inner surface of canister lid
- Hinge
- Edges of concentrator
- Inner surface of canister not covered by collector array
- Collector coupon support structures



Genesis, SOHO L1 Orbits



Genesis:
12 Sep 2001 – 7 Sep 2004

Genesis:
30 Nov 2001 – 1 Apr 2004

SOHO:
30 Nov 2001 – 28 Feb 2003



Solar Wind Statistics

Only the integrated effect of bulk solar wind is of interest to us!

LANL 30 March 2003

	Bulk	CME	CH (fast)	Slow	SRC Lid	Conc
Total exposure time	485.09	122.84	98.20	254.00	501.76	467.19
Proton Fluence (days) ($\times 10^{16}$ #/cm ²)	1.2034	0.2847	0.1993	0.6868	1.2268	0.2281
Fluence other regimes		0.0013	0.0010	0.0049		
He/H ratio	0.0399	0.0469	0.0381	0.0378	0.0401	0.0398
Array changes		145	80	97		

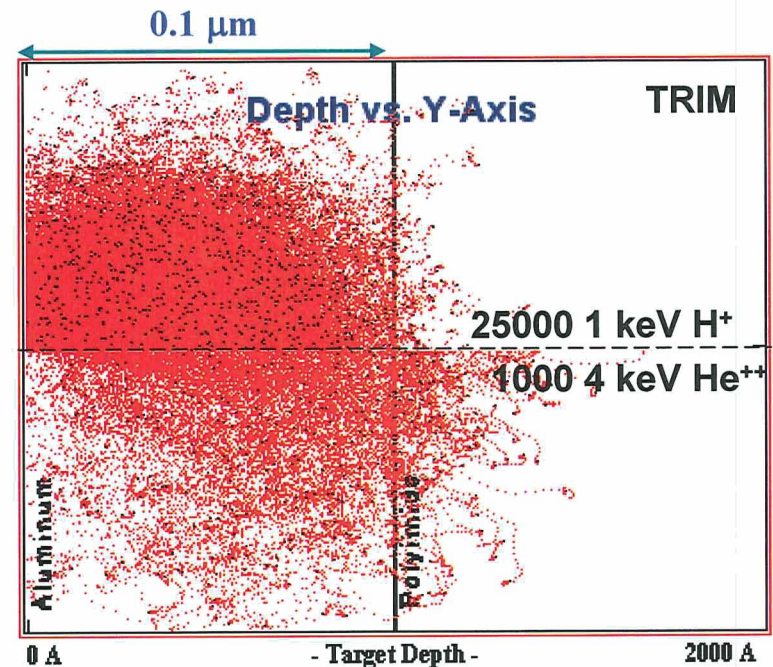
SOHO estimate was 1.3855×10^{16}

(adapted from <http://genesission.jpl.nasa.gov/>)



Solar Wind as Radiation Environment

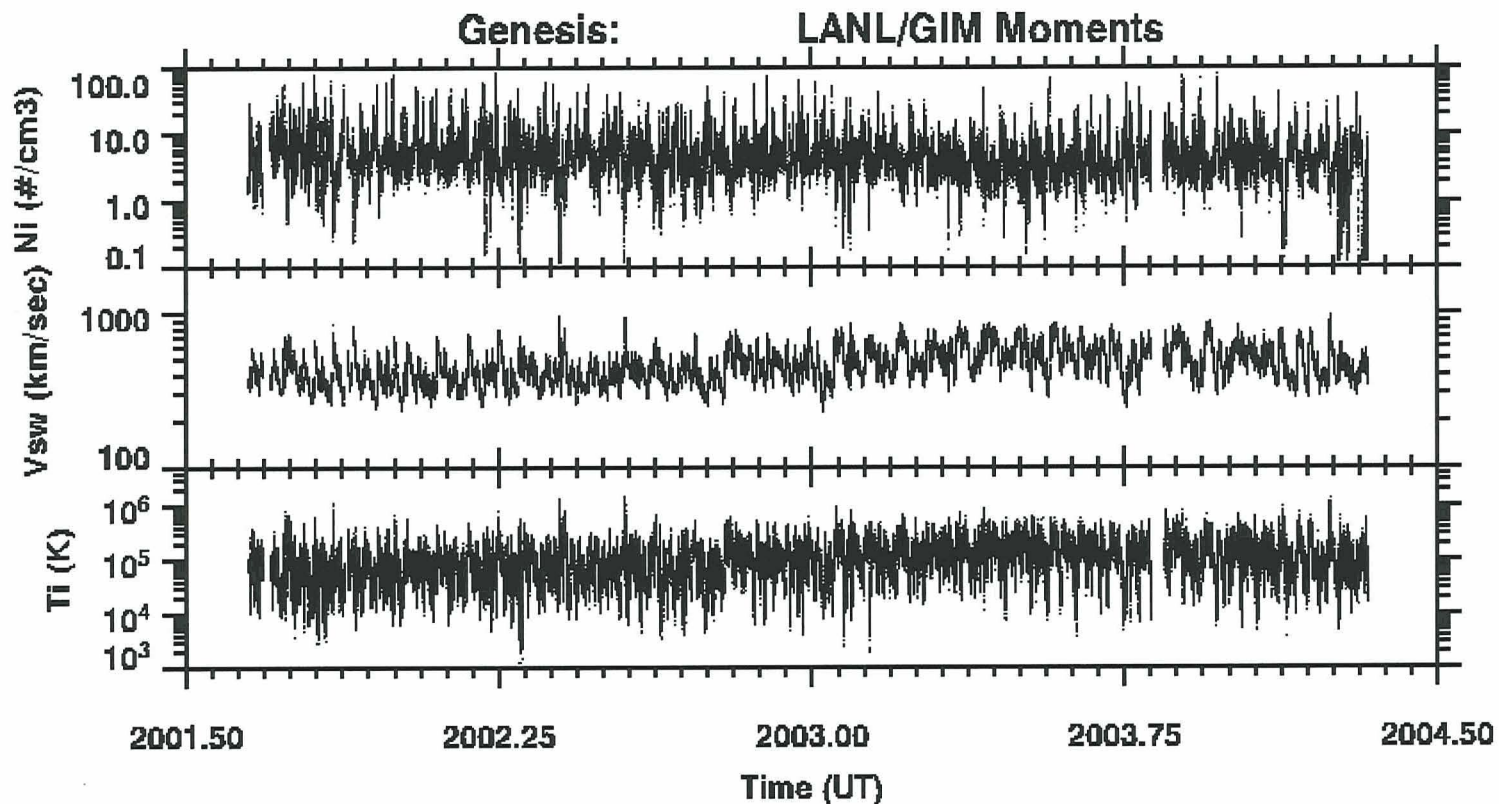
- Solar wind is generally considered a benign radiation environment
 - Solar wind velocity ~400 km/sec to 800 km/sec, mean ~450 km/sec
 - Kinetic energy of H^+ ~ 0.21 keV to 3.3 keV, mean 1.1 keV
 - Kinetic energy of He^{++} ~ 0.84 keV to 13 keV, mean 4.2 keV
 - H^+ flux ~ $NV \sim (7 H^+/cm^3)(450 \times 10^3 m/s) \sim 3.2 \times 10^8 H^+/cm^2\text{-sec}$
 - $He^{++}/H^+ \sim 0.038$ He^{++} flux ~ $0.12 \times 10^8 H^+/cm^2\text{-sec}$
 - Fluence
 - $H^+ \sim 9.9 \times 10^{15} H^+/cm^2\text{-year}$
 - $He^{++} \sim 3.8 \times 10^{14} H^+/cm^2\text{-year}$
- Solar wind penetration depths are only fractions of a micron
 - Bulk materials impacted only on “surfaces”
 - 1000 Å (0.1 μm) coating is impacted throughout the material





Genesis Radiation Model

- Genesis Ion Monitor (GIM) provides ion flux in-situ measurements
- Los Alamos National Laboratory provides ion moments on web site
- Reconstruct differential flux from moments





Differential Flux Reconstruction Technique

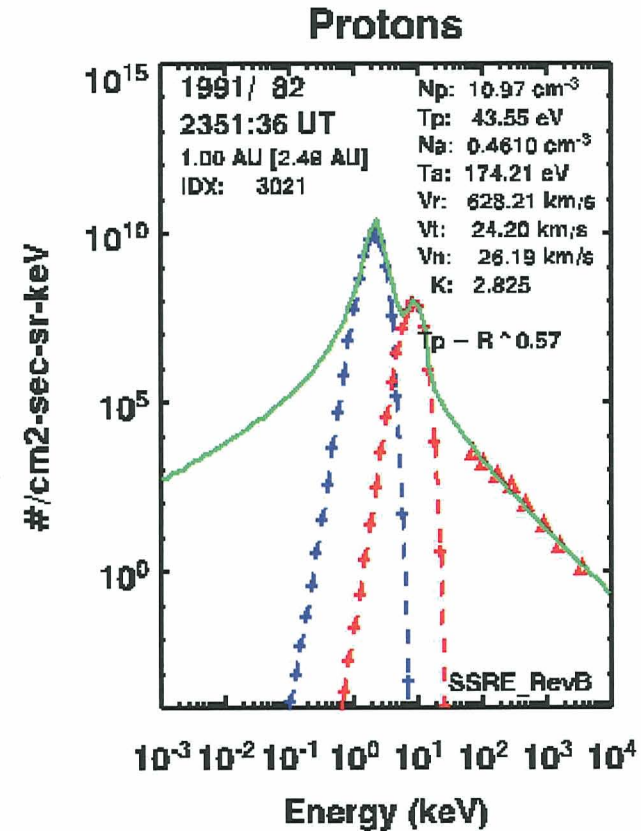
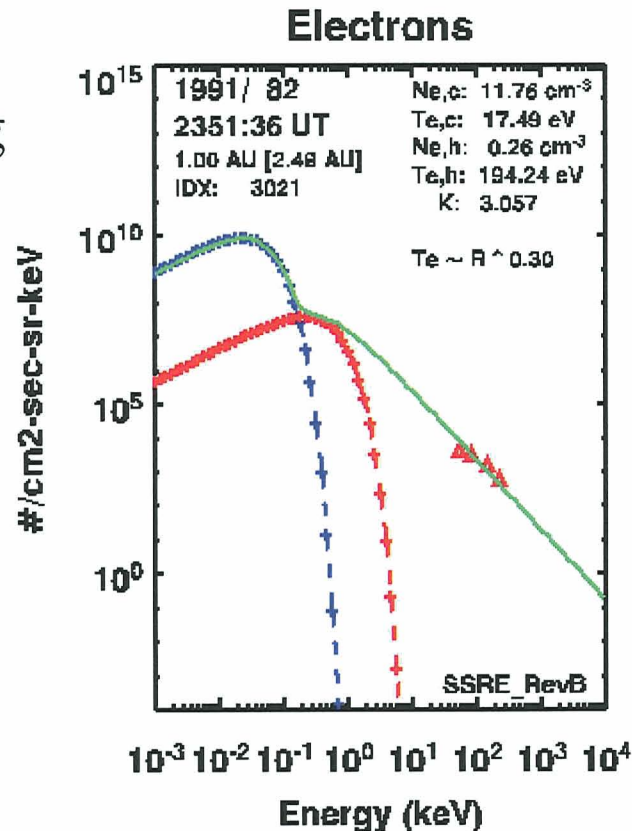
Ulysses SWOOPS plasma moments and LEFS, LEMS energetic particle flux

Radial scaling

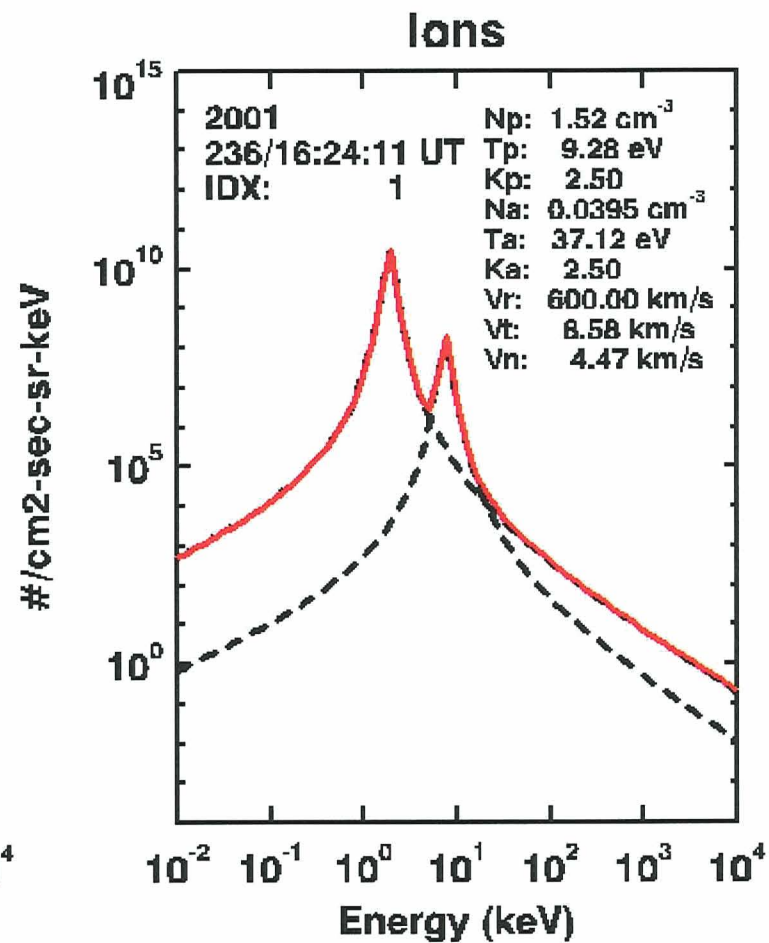
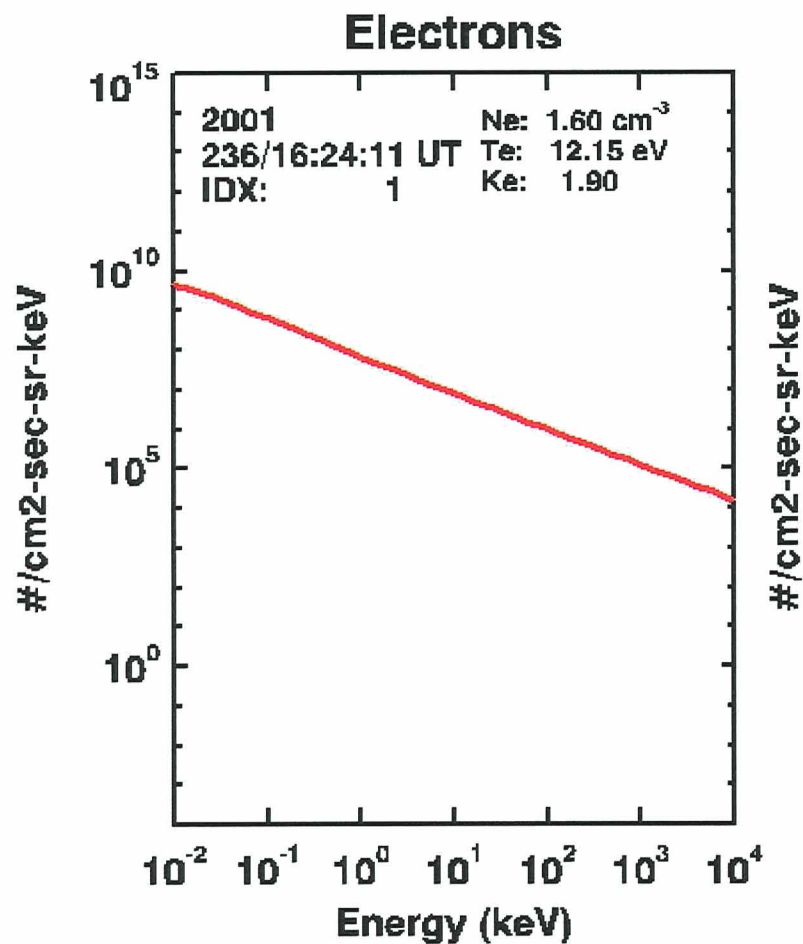
$$N_p \sim R^{-2}$$

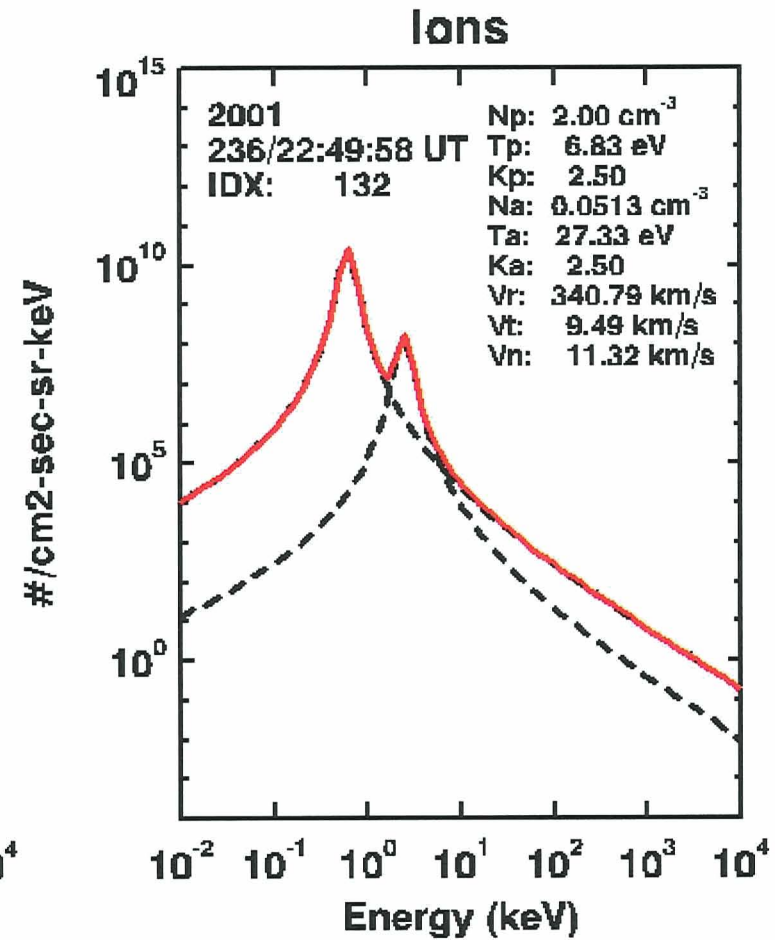
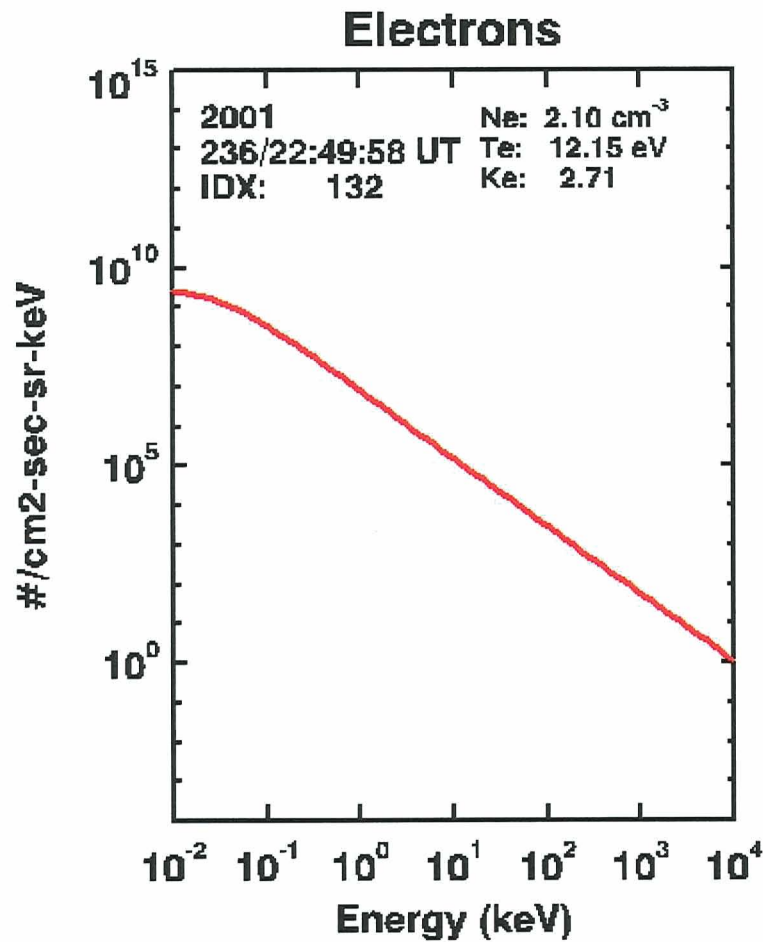
$$T_p \sim R^{-0.57}$$

$$V_p \sim R^0$$

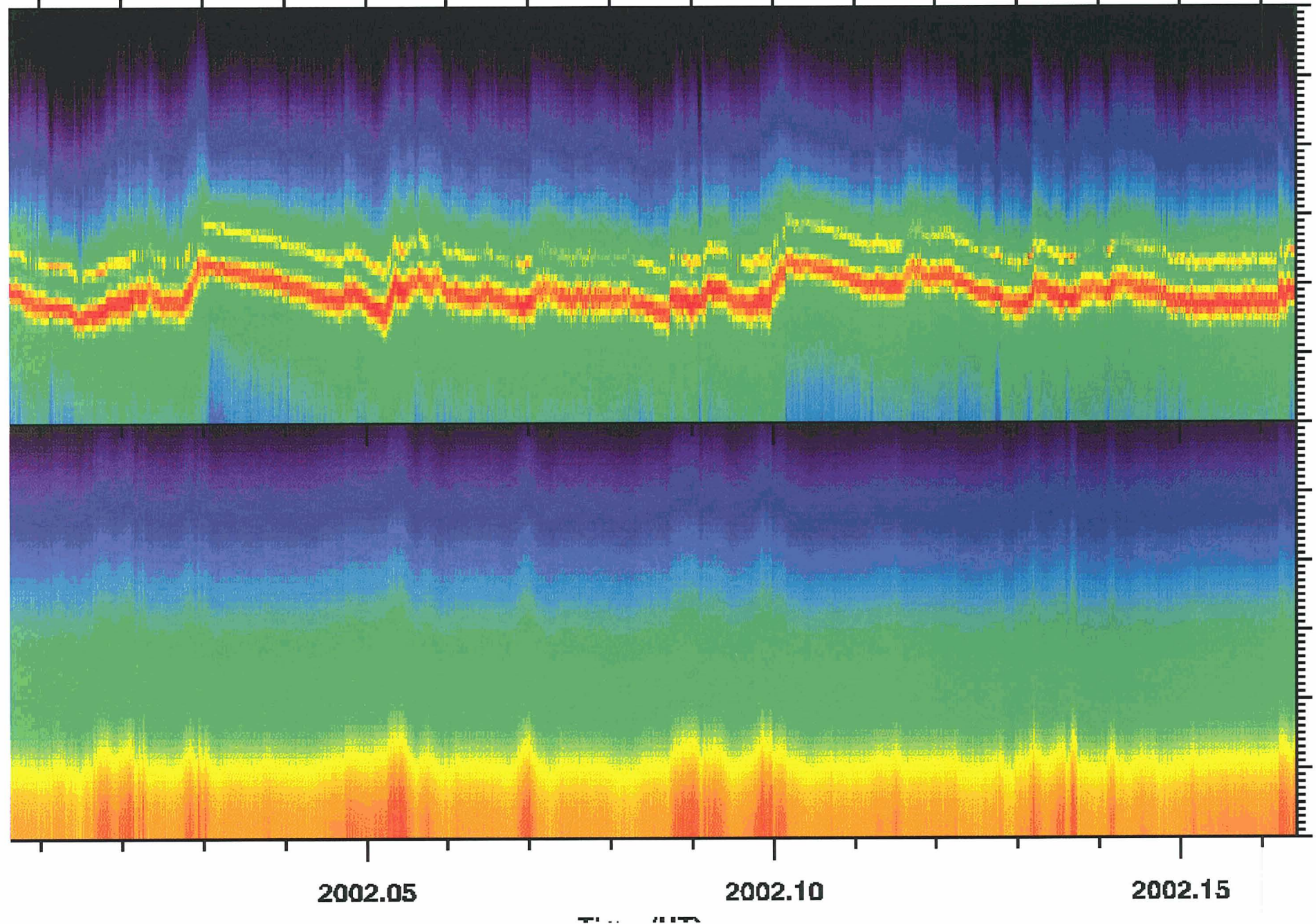


Minow et al., 2005

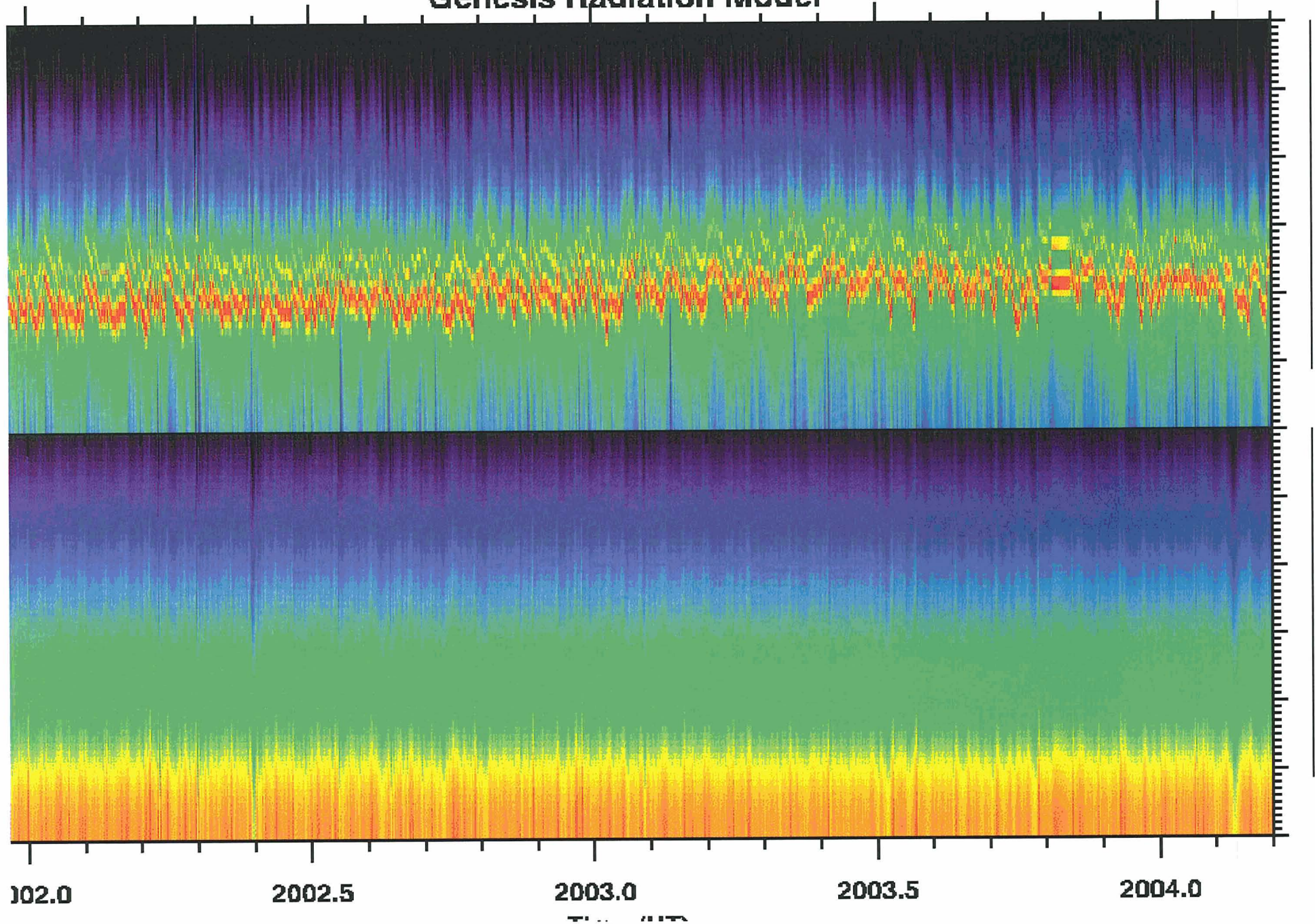




Genesis Radiation Model



Genesis Radiation Model





Genesis/L1 Radiation Environment

“Interim” Model

$$N_e \sim N_p + 2N_{He}$$

$$N_{He} = \chi N_p$$

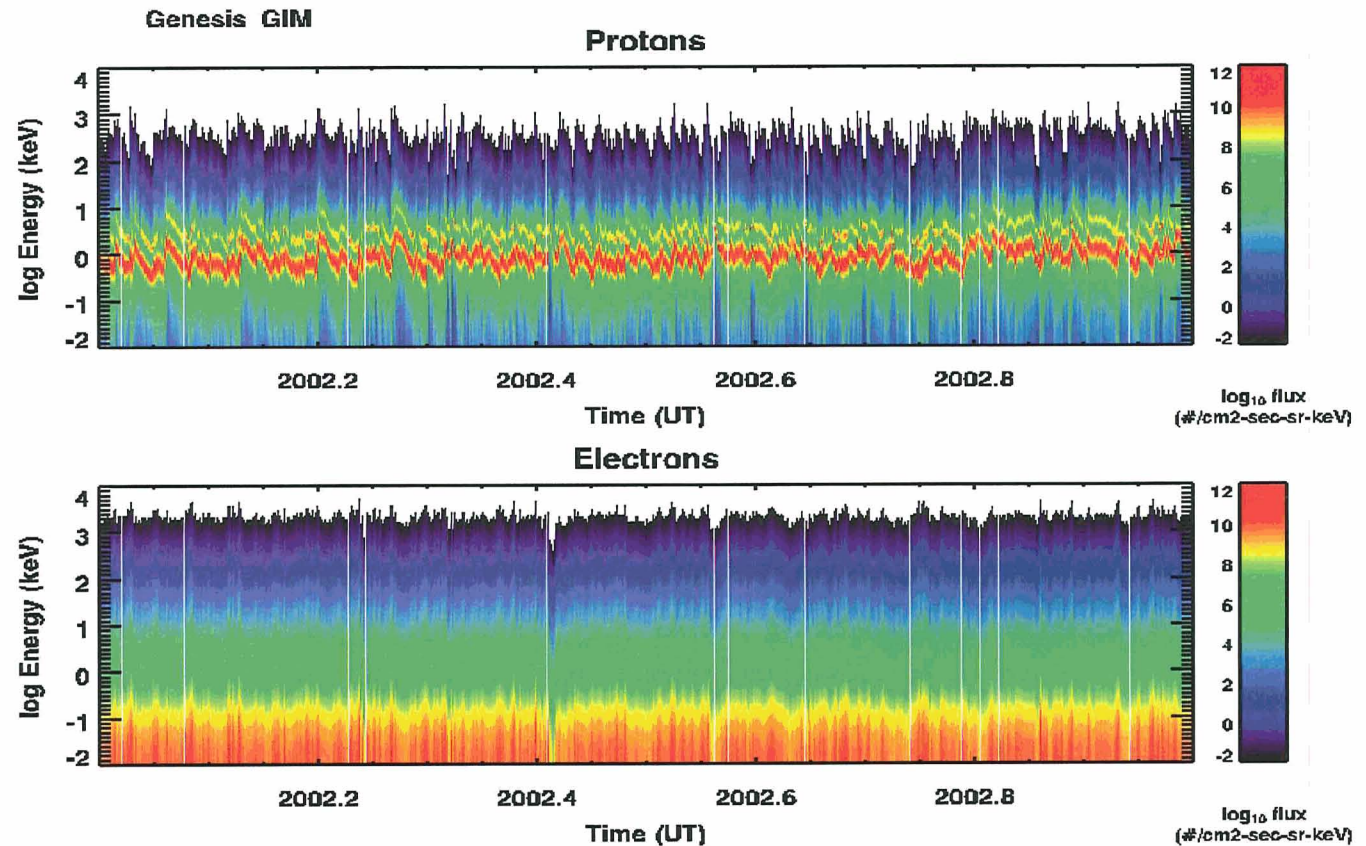
$$T_e = 1.41 \times 10^5 \text{ K}$$

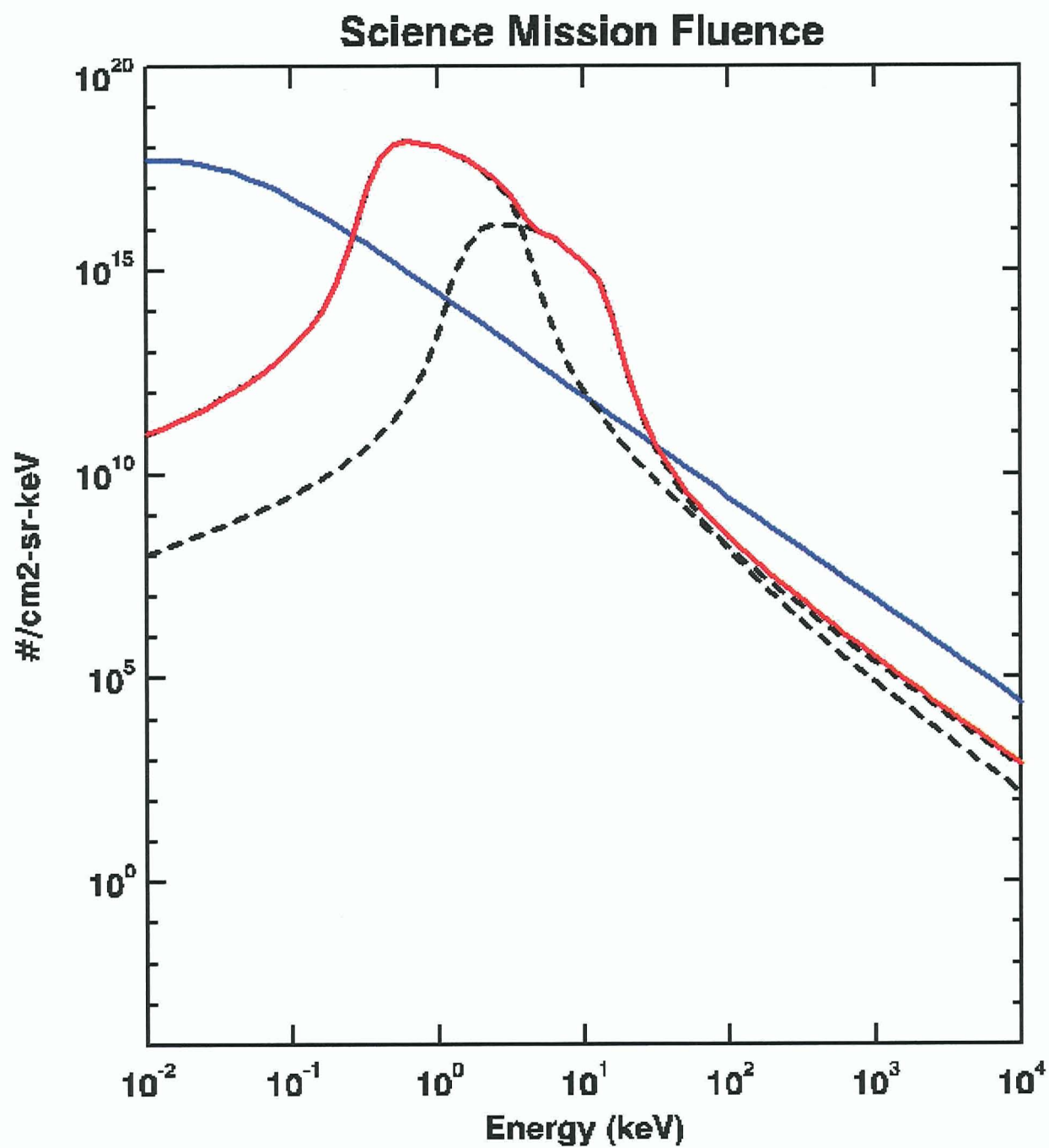
[Newberry et al., 1998]

$$V_{r,e} \sim V_{r,p} \sim V_r$$

$$T_{He} = T_p$$

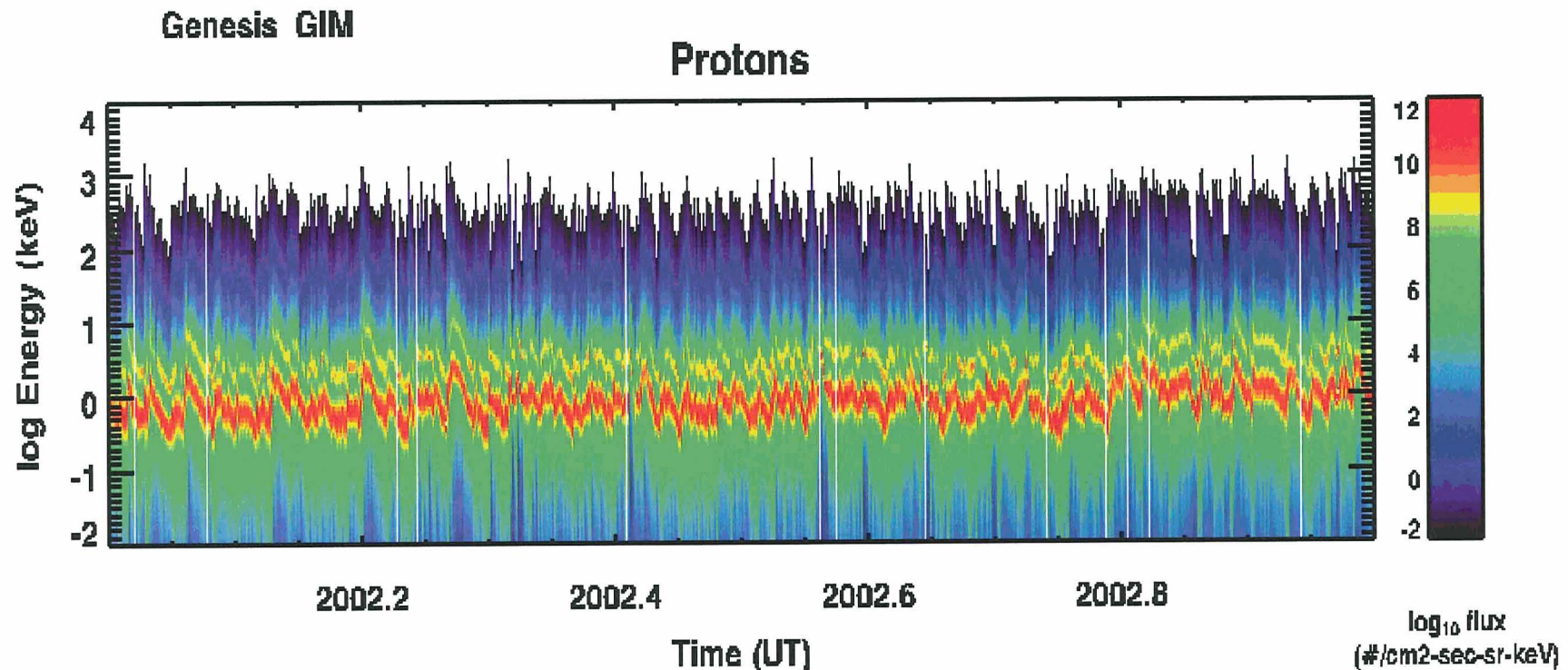
$$\kappa = 3.5 \text{ for H, He, } e^-$$







Reconstructed Genesis Ion Flux

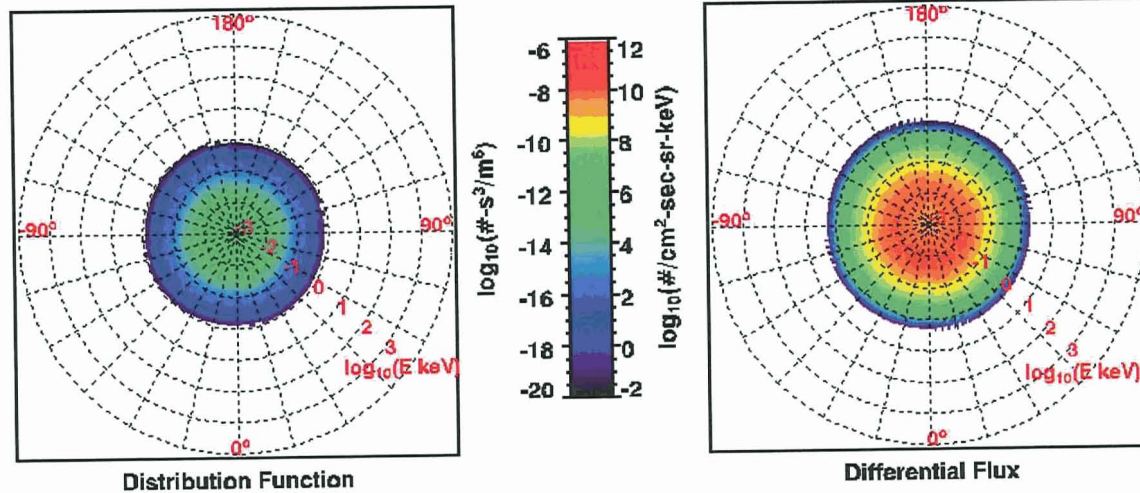


- Reconstructed environment provides energy dependent H, He environments for evaluation of:
 - Energy dependent sputter yields
 - Variation in ion implantation depths

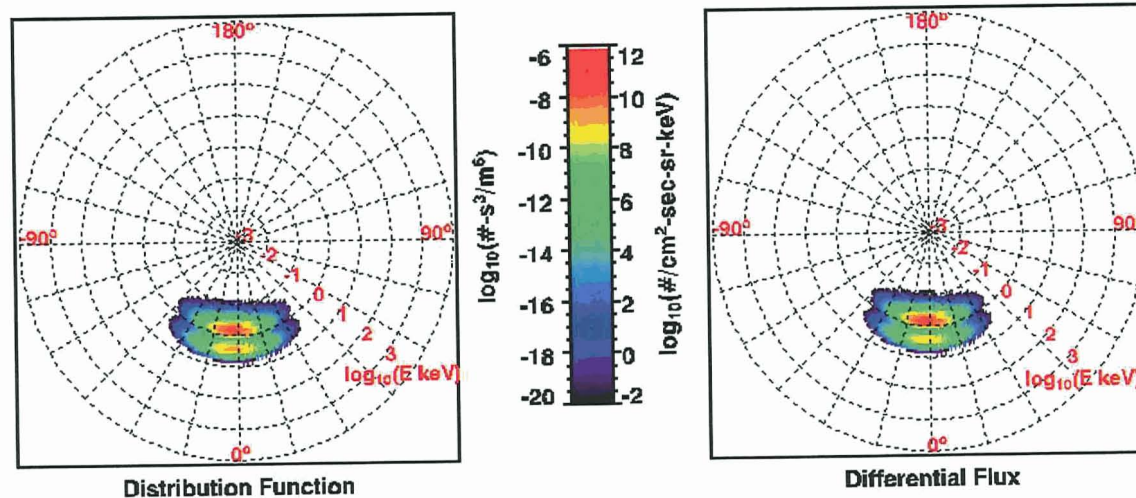


Reconstructed 2-D Distribution Functions

Electron (Maxwellian)



Proton and Helium (Maxwellian)





Genesis Electron Monitor Data

834 eV

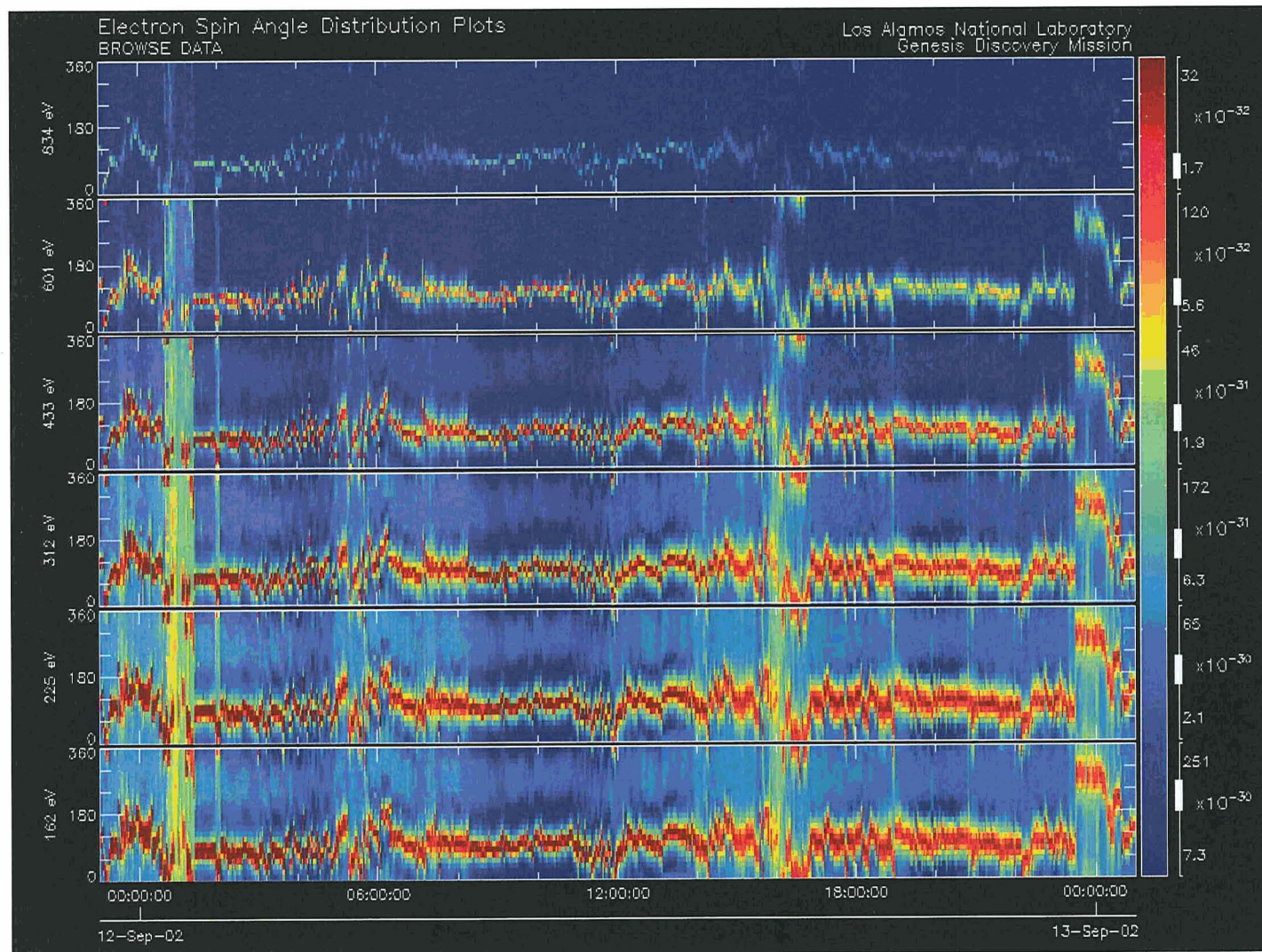
601 eV

433 eV

312 eV

225 eV

162 eV





Genesis/L1 Radiation Environment

- **Status**

- Environments analysis
 - Completed database for characterizing environment based on GIM ion moments
 - Collected, merged ACE LEFS, LEMS ion, electron flux measurements for period coinciding with Genesis observations
 - Gap analysis
- Completed software for preliminary environment based on GIM ion moments, derived electron environments

- **Remaining work**

- Complete “interim” version using full 1 Dec 2001 to 1 Apr 2004 GIM moments, derived electron environments
- Kappa fits using ACE Low Energy Foil Spectrometer (LEFS), Low Energy Magnetic Spectrometer (LEMS)
 - Software has been used for Geotail, Ulysses L2-CPE environments
- Complete ion, electron dose as function of depth
- Complete documentation



Genesis/L1 Radiation Environment

- **Summary:**

- Engineering analysis of Genesis Science Capsule (SC) materials returned from L1 provides a unique opportunity to investigate degradation of materials exposed to the L1 space environment
- Incorporate Genesis GEM/GIM particle flux measurements with energetic particle observations from other L1 spacecraft to construct ion, electron energy flux spectra, fluence required for materials degradation analysis
- Adapt results and include as L1 environment for the L2-Charged Particle Environment (L2-CPE) model
- Products are
 - Charged particle (radiation) environment for use in engineering analyses of Genesis returned hardware,
 - L1 environment for L2-CPE model,
 - Documentation